United States Patent [19]

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[11] **Patent Number:** **4,569,635**

[45] **Date of Patent:** **Feb. 11, 1986**

[54] **HYDROKINETIC AMPLIFIER**

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[21] Appl. No.: **612,742**

[22] Filed: **May 21, 1984**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 517,821, Jul. 27, 1983, abandoned, which is a continuation-in-part of Ser. No. 236,918, Feb. 23, 1981, abandoned, which is a continuation-in-part of Ser. No. 42,967, May 29, 1979, abandoned.

[51] **Int. Cl.**[4] **F04F 5/00**

[52] **U.S. Cl.** **417/196;** 417/178; 417/197

[58] **Field of Search** 417/197, 196, 176, 77, 417/54, 192, 151, 198, 181, 174, 178, 177

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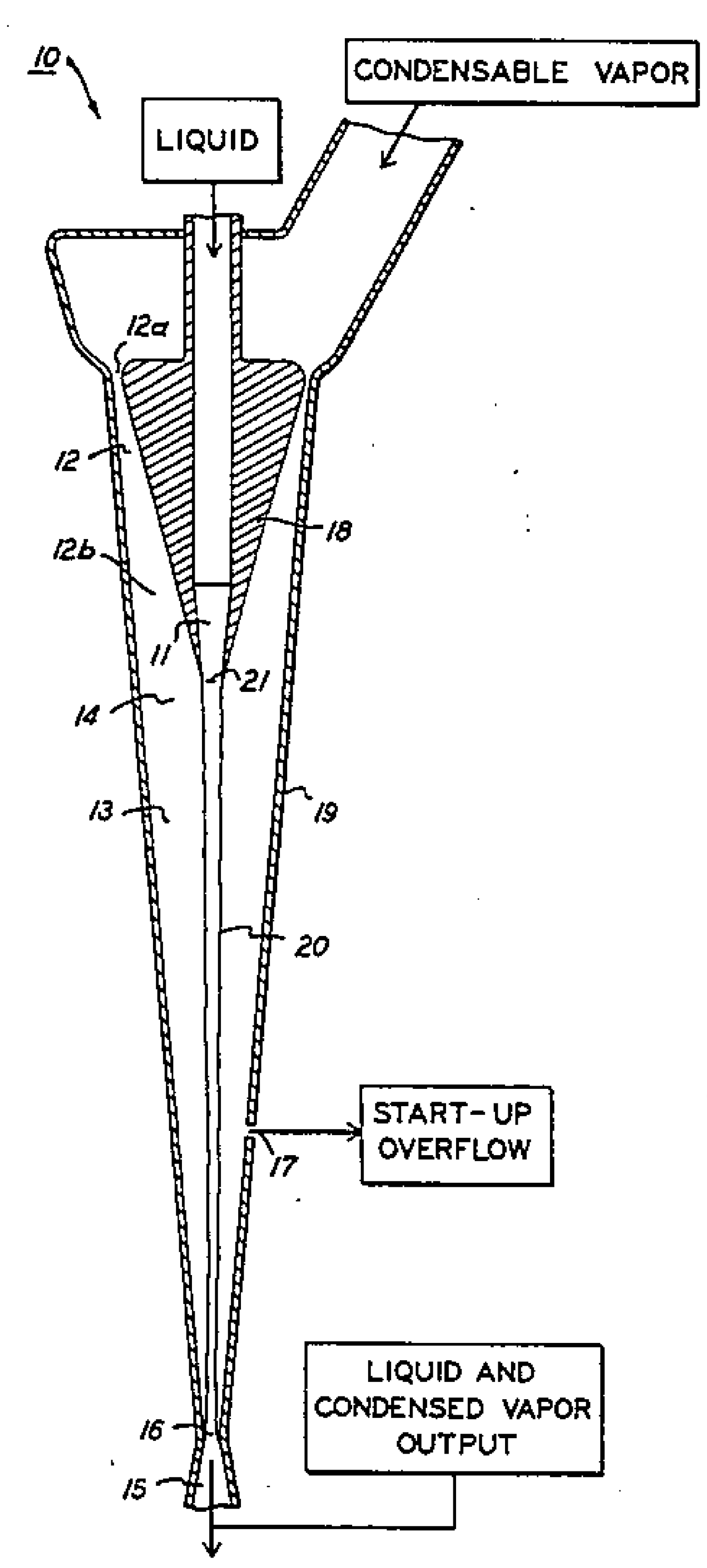
[57] **ABSTRACT**

A hydrokinetic amplifier **10** uses liquid and vapor input nozzles **11** and **12** discharging into an acceleration chamber **13** downstream from which a diverging diffuser **15** extends. Liquid nozzle **11** forms a free liquid jet **20** that extends for a substantial distance through acceleration chamber **13,** and vapor flowing at a much higher speed into acceleration chamber **13** surrounds, impinges on, and condenses into free liquid jet **20.** Collapse of the condensing vapor forms a suction into which more vapor flows. Acceleration chamber **13** gradually converges from an ingress region **14** receiving liquid and vapor to an egress region **16** flowing mostly liquid into diffuser **15.** Vapor nozzle **12** has a throat region **12***a* arranged upstream of the discharge region **21** of liquid nozzle **11** and an expanding region **12***b* extending from throat region **12***a* downstream toward ingress region **14** of acceleration chamber **13** so that vapor is expanding when it contacts the liquid. The vapor surrounds and travels in the direction of free liquid jet **20** so that substantially more than half of the expanding vapor contacts and condenses in liquid jet **20,** transferring momentum energy from the vapor to the liquid to accelerate the liquid toward egress region **16.**

18 Claims, 5 Drawing Figures



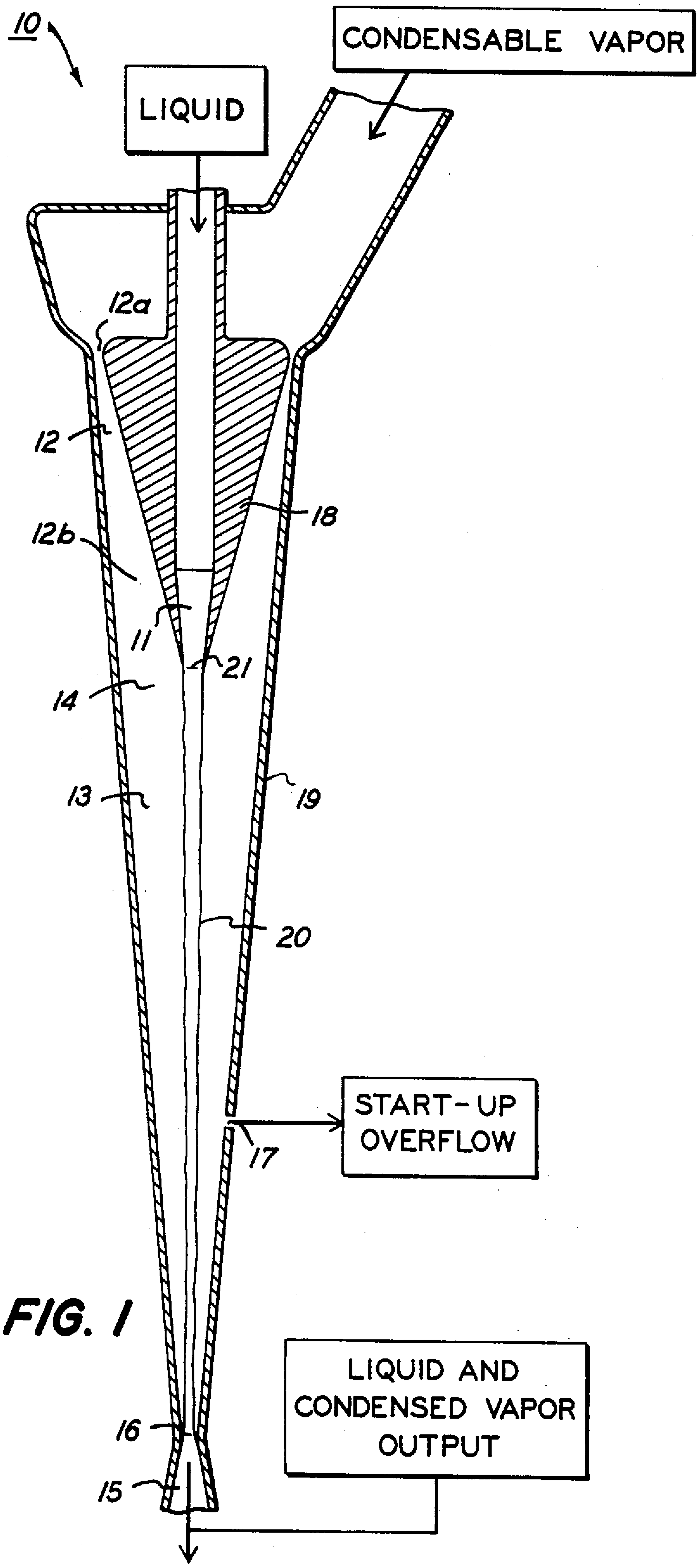


FIG. 1

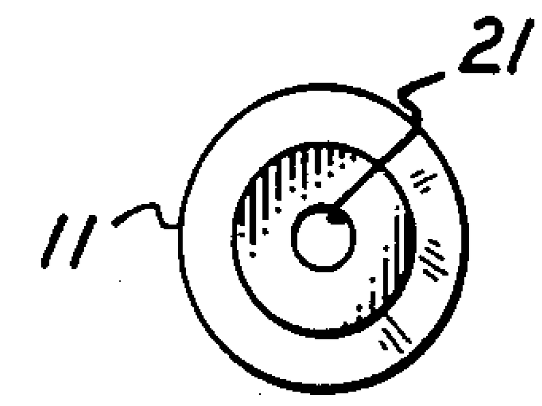


FIG. 2

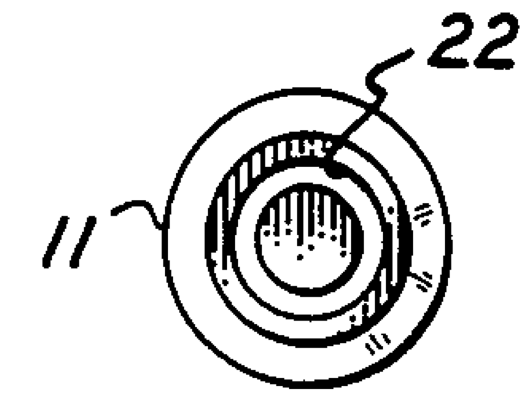


FIG. 3

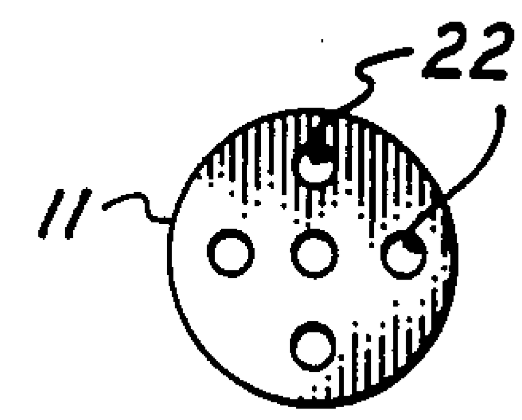


FIG. 4

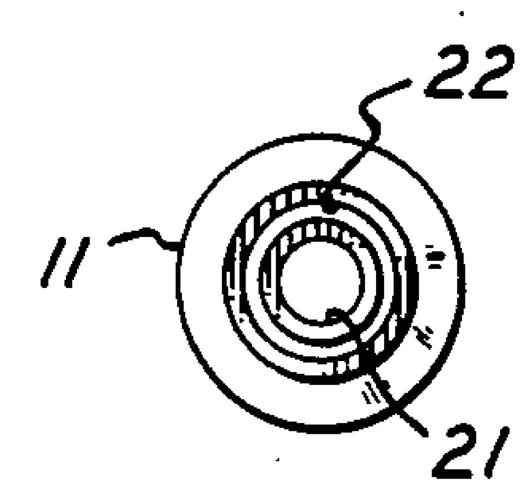


FIG. 5

HYDROKINETIC AMPLIFIER

RELATED APPLICATIONS

This application is a continuation-in-part of my parent application Ser. No. 517,821, filed July 27, 1983, entitled Hydrokinetic Amplifier, which was a continuation-in-part of my grandparent application Ser. No. 236,918, filed Feb. 23, 1981, entitled Hydrokinetic Amplifier, which was a continuation-in-part of my great grandparent application Ser. No. 042,967, filed May 29, 1979, entitled Fluid Pressure Amplifier and Condenser. All preceding applications were abandoned upon filing of successor applications, and the full disclosure of my parent application Ser. No. 517,821 and grandparent application Ser. No. 236,918 are hereby incorporated into this continuation-in-part application.

BACKGROUND

Since the mid-1800's, injectors have exploited the ability of steam to combine with water into which the steam condenses, transferring its momentum energy, for outputting liquid at a pressure higher than the steam input pressure. My hydrokinetic amplifier also transfers vapor energy to liquid to increase the output pressure, but it does this much more efficiently than an injector. With hindsight knowledge of how my hydrokinetic amplifier works, it is clear that steam injectors suffered large friction losses in accelerating water while the water engaged in internal wall. My hydrokinetic amplifier accelerates liquid in a free jet surrounded by vapor and avoids the large friction losses from accelerating water along a wall.

Some prior art jet pumps, such as fluid heaters, have also used a liquid jet spaced from a wall and surrounded by vapor, but these have failed to achieve a substantial pressure gain. Hindsight now suggests that they could have been designed to increase pressure, but actual practice shows that they were designed merely to heat the liquid. They failed to accelerate the vapor to a high velocity, they lacked a sufficient distance for the vapor to condense in the liquid and transfer its kinetic energy before reaching a diffuser, and they lacked a small enough discharge opening to pass mostly liquid through a diffuser for efficiently converting kinetic energy to pressure.

My hydrokinetic amplifier suffers none of these shortcomings. It is structured to maximize the kinetic energy of the vapor, transfer as much of that kinetic energy as possible to a free liquid jet, keep friction losses to a minimum, and efficiently convert liquid velocity to liquid pressure at the output diffuser. Thus, by a combination of efficiency-improving strategies, my hydrokinetic amplifier produces a surprisingly large pressure amplification that can exceed the sum of the absolute liquid and vapor input pressures by a factor of four. This readily beats injectors, the best of which cannot double the absolute liquid and vapor input pressures.

The collapse of vapor condensing within my hydrokinetic amplifier produces a suction that can draw in operating vapor from a subatmospheric pressure source. This allows my hydrokinetic amplifier to produce a substantial pressure gain from a subatmospheric pressure vapor—a feat unachievable by injectors, which cannot function at all with subatmospheric pressure vapor, or by fluid heaters, which do not produce more

than incidental pressure gain and require a pressurized source of liquid to entrain the subatmospheric vapor.

The suction can also draw in subatmospheric pressure liquid at the same time that subatmospheric pressure vapor is providing the motive power. So unlike prior art jet pump devices that require a pressurized fluid to entrain a subatmospheric pressure fluid, my hydrokinetic amplifier can operate on subatmospheric pressure vapor without any high pressure entrainment. This allows my hydrokinetic amplifier to vaporize and condense liquids at subatmospheric pressures without using vacuum pumps.

The superior capabilities of my hydrokinetic amplifier can be exploited in a variety of ways that include condensing, evaporating, cooling, pumping, forming jets, entraining fluids, transferring heat, liquifying gas, and producing warmed and pressurized liquid output.

SUMMARY OF THE INVENTION

My hydrokinetic amplifier discharges a free liquid jet into an ingress region of an acceleration chamber having a gradually converging wall so that the jet can be accelerated through the acceleration chamber without contacting the wall and thus incurring friction losses before reaching an egress region. Vapor also flows into the ingress region of the acceleration chamber through a vapor nozzle that directs expanding and much higher velocity vapor to surround and travel in the direction of the free liquid jet. The vapor nozzle, preferably surrounding the liquid nozzle, has a throat region arranged upstream of the discharge region of a liquid nozzle and an expanding region arranged from the throat region downstream toward the ingress region of the acceleration chamber. This can accelerate vapor to supersonic velocity at the ingress region. Since both the liquid and the much higher velocity vapor are proceeding in the same direction toward the egress region, a large part of the momentum energy of the speeding vapor transfers to the liquid as the vapor contacts and condenses in the liquid.

The free liquid jet accelerating through the acceleration chamber is long enough for condensing the merging vapor before reaching the egress region. Substantially more than half, and preferably at least about 90%, of the vapor condenses in the free liquid jet before reaching the egress region, and preferably the flow through the egress region is at least about 90% liquid. This often gives the egress region a smaller cross-sectional area than the discharge region of the liquid input nozzle, and it allows a diffuser extending downstream of the egress region to efficiently convert liquid velocity to pressure.

DRAWINGS

FIG. **1** is a schematic diagram of a preferred embodiment of my hydrokinetic amplifier; and

FIGS. **2–5** are schematic views of the discharge ends of various preferred liquid input nozzles for the amplifier of FIG. **1**.

DETAILED DESCRIPTION

My hydrokinetic amplifier **10**, as schematically shown in FIG. **1**, includes a liquid input nozzle **11**, a vapor input nozzle **12**, and an acceleration chamber **13** with an ingress region **14** and an egress region **16**, downstream from which a diffuser **15** extends. Liquid nozzle **11** forms a free liquid jet **20** that extends from ingress region **14** through acceleration chamber **13** to egress region **16** where it enters diffuser **15**. The gradually converging wall **19** of acceleration chamber **13** preferably has a gap **17** arranged between the ingress and egress regions to facilitate start-up.

My hydrokinetic amplifier can have many configurations, shapes, and proportions other than the ones illustrated, provided its components embody the principle features and variations described below.

LIQUID INPUT NOZZLE

The main function of liquid input nozzle **11** is to form and direct free liquid jet **20** into ingress region **14** of acceleration chamber **13** so that liquid jet **20** passes through acceleration chamber **13** without contacting converging wall **19** before reaching egress region **16**. Nozzle **11** is preferably a converging liquid nozzle with a discharge area **21** that determines the size and flow rate of jet **20** for a given difference between liquid input pressure and the lower pressure within acceleration chamber **13**. Nozzle **11** is also preferably coaxial with acceleration chamber **13** and oriented to aim jet **20** vertically downward as illustrated, although other configurations and orientations can be made to work.

Among the many possible variations for liquid input nozzle **11**, its discharge area **21** can be circular as shown in FIG. **2**, annular as shown by opening **22** in FIG. **3**, multiple openings **23** as shown in FIG. **4**, or even multiple nozzles such as circular nozzle **21** surrounded by annular nozzle **22** as shown in FIG. **5**. The discharge area, meaning the actual area of any opening through which liquid is discharged by nozzle **11** into acceleration chamber **13**, establishes the flow rate for any given liquid pressure drop across the nozzle.

VAPOR INPUT NOZZLE

Vapor input nozzle **12** preferably surrounds liquid input nozzle **11** and directs a condensable vapor into acceleration chamber **13** to flow in the same general direction as liquid jet **20**. Vapor nozzle **12** has a constricted throat region **12*a*** arranged upstream of discharge region **21** of liquid nozzle **11**. Downstream of throat region **12*a***, vapor nozzle **12** has an expanding region **12*b*** formed between acceleration chamber wall **19** and an annular surface **18** around liquid nozzle **11**. A sufficiently low suction pressure, caused by vapor condensing in acceleration chamber **13**, preferably draws incoming vapor at sonic velocity through throat region **12*a*** so that vapor expanding into expansion region **12*b*** accelerates to supersonic velocity upon entering ingress region **14** and contacting liquid jet **20**. Vapor flow at a high rate and vapor acceleration to a high velocity are both desirable to produce a large liquid pressure gain.

Vapor nozzle **12** is preferably configured to produce maximum vapor momentum or thrust, and this can be derived from the art of rocket nozzles. Since high velocity vapor should surround and travel in the same direction as liquid jet **20**, vapor nozzle **12** is preferably annular. The surrounding vapor helps keep liquid jet **20** away from contact with converging wall **19**, and high velocity vapor speeding in the same direction as liquid in jet **20** is optimum for transferring the kinetic energy of the vapor to the liquid as the vapor contacts the liquid and condenses.

ACCELERATION CHAMBER

Acceleration chamber **13** has an adequate diameter at its ingress region **14** to receive high velocity vapor discharged from expansion region **12*b*** of the vapor nozzle so that the vapor surrounds, merges with, and accelerates the liquid toward egress region **16**. The wall **19** of acceleration chamber **13** preferably converges downstream at a taper of, for example, 2.5°. The wall can also be parallel or slightly divergent without appreciably diminishing performance. A long and gently converging acceleration chamber gives jet **20** an adequate length for optimum performance and directs vapor to impinge on jet **20** at a small angle to its direction of travel for effective transfer of momentum from vapor to liquid.

Vapor collapses as it condenses in liquid jet **20**, and most of the vapor condenses before reaching egress region **16**. The convergence of wall **19**, directing vapor into jet **20**, has a vapor-compressing tendency that is at least partially offset by the collapse of condensing vapor tending to cause vapor expansion. The pressure of the vapor stream flowing toward egress region **16** does not necessarily increase.

An ample length for free liquid jet **20** enhances its ability to condense merging vapor and accelerate to a high velocity that converts to a high pressure gain. It also helps merge and condense a high flow rate of incoming vapor transferring energy to the liquid. In prototypes of my hydrokinetic amplifier, I have operated free jets at lengths of over 25 times the diameter of egress region **16**, and I have not yet discovered any upper limit for the jet length.

Substantially more than half, and preferably at least about 90%, of the incoming vapor condenses in liquid jet **20** during its passage through acceleration chamber **13**. By the addition of condensate, the liquid increases in both velocity and flow rate so that the cross-sectional area of jet **20** diminishes as the jet advances. The discharge converging through egress region **16** is mostly liquid, which is preferred for efficient conversion of liquid velocity to pressure.

Egress region **16** has a minimum cross-sectional area that is preferably smaller than the discharge area **21** of liquid nozzle **11** and preferably only slightly larger than the cross-sectional area of the liquid jet flowing through. The outflow through egress region **16** is preferably at least about 90% liquid. The outflowing liquid engaging the converging and diverging wall of diffuser **15** efficiently converts the liquid's kinetic energy to output pressure.

OPERATION

My hydrokinetic amplifier can be operated under different conditions for different results such as high output pressure, high output temperature, high rate of vapor condensation, low vapor supply pressure, low liquid supply pressure, and high fluid entrainment capability. All these objectives involve converting vapor energy to a high velocity flow and transferring the kinetic energy of this to slower moving liquid in a free jet. Different objectives can also be mixed, and amplifier **10** can be structured and operated to fit its performance to a variety of circumstances.

Structural variations to accomplish different objectives can include size and shape of discharge area **21** of input nozzle **11**, axial position of liquid nozzle **11**, location and size of throat **12*a*** of vapor nozzle **12**, angle and length of expansion region **12*b***, surface area of free liquid jet **20**, volume and diameter of ingress region **14** of acceleration chamber **13**, convergence angle and length of acceleration chamber **13**, size of egress region **16** and its distance from nozzle **11**, and divergence angle and length of diffuser **15**. Besides structural variations, liquid and vapor input pressures, temperatures, and flow rates can vary; different fluids can be entrained; and many different operating liquids and vapors can be used. These possibilities all work within general operating principles and guidelines for varying the desired effects as explained below.

START-UP

Overflow **17** is preferred for most start-ups. Liquid and vapor can then be admitted to acceleration chamber **13** and can overflow through gap **17** until condensing vapor sufficiently accelerates jet **20** so that high velocity liquid flow fits through egress region **16**. When this happens, a low pressure occurs at overflow **17**, which preferably closes a check valve to prevent back flow from atmosphere.

If amplifier **10** is arranged to start with a low pressure discharge so it does not have to overcome a back pressure, overflow **17** can be omitted. Then start-up can be accomplished by a reduced flow liquid jet **20** small enough to fit through egress region **16**. Vapor condensing in such a reduced flow start-up jet creates suction within chamber **13** and accelerates the jet so that the liquid flow can be increased to full operating flow.

CONDENSATION AND EVAPORATION

Vapor collapsing as it condenses in jet **20** forms a suction, drawing more vapor to chamber **13**. This allows my amplifier to operate with subatmospheric pressure vapor drawn into the even lower pressure prevailing within acceleration chamber **13**. Subatmospheric pressure liquid can also be drawn into acceleration chamber **13**, even while my amplifier is operating with subatmospheric pressure vapor to produce a superatmospheric pressure output.

For subatmospheric pressure operation, a start-up arrangement must be used to draw liquid and vapor into acceleration chamber **13** so that vapor condensation there can create a suction drawing in subatmospheric pressure inputs. The ability of my hydrokinetic amplifier to draw operating vapor from a subatmospheric pressure source can be exploited in distillation, evaporation, and cooling processes.

The liquid temperature of jet **20** must be low enough to condense the incoming vapor; and for water and water vapor, I prefer a temperature difference of at least about 25°-30° C. Larger temperature differences also work, and minimum temperature differences vary with different liquids and vapors.

The condensation rate is also affected by the surface area of jet **20** and the velocity and density of the vapor. A larger jet surface area can condense more vapor by making more liquid surface available for impinging contact with vapor. High velocity and higher density vapors impinge vapor molecules onto the liquid jet at a faster rate and thus increase the condensation rate. As vapor accelerates to supersonic velocity, its temperature drops; and this decreases the temperature difference between the vapor and liquid. Condensation can still occur, but will be enhanced by a larger difference in temperature between the sources of incoming liquid and vapor.

Sonic velocity vapor passing through throat **12*a*** of vapor nozzle **12** is preferred and is easily attained by a suction in ingress region **14** of 0.57 times the pressure of the vapor source. With acceleration chamber **13** dimensioned to receive expanding vapor, with an adequate surface area of jet **20**, with an adequate temperature difference between the vapor and liquid sources, and with a properly shaped vapor throat **12*a*** and expansion region **12*b***, vapor can attain supersonic velocity in acceleration chamber **13**. This increases the kinetic energy of the vapor and provides substantial vapor momentum that transfers to liquid, accelerating the liquid to a higher velocity and yielding a higher output pressure.

If a low pressure output from diffuser **15** is satisfactory and maximum vapor flow is desired, then egress region **16** can be as large as or slightly larger than discharge area **21**. An egress region of 1.6 times discharge area **21** is known to operate at moderate pressure amplification. This allows vapor input at a larger flow rate than can be condensed in the liquid jet before it reaches egress region **16**, and it allows the oversupply of uncondensed vapor to flow with the liquid through egress region **16** whereupon the excess vapor condenses in diffuser **15**.

My hydrokinetic amplifier has operated with vapor at subatmospheric pressures as low as 1.7 psia, or a vacuum of 27 inches of mercury. The low density of low pressure vapors makes the vapor condensation rate relatively small, but the vapor can be withdrawn from a low temperature source of liquid. Even such low pressure vapor can produce a sufficient pressure gain so that incoming water at about 12 psia is output at more than atmospheric pressure. Egress region **16** is preferably a little larger than liquid nozzle discharge region **21** to favor increased condensation instead of pressure gain.

PRESSURE AMPLIFICATION

For maximum pressure amplification, I prefer supersonic vapor, which has more transferable momentum and is more effective at driving vapor molecules into liquid molecules to accelerate the liquid. Supersonic vapor does not condense quite as rapidly as sonic velocity vapor, so jet **20** is preferably made especially long. Also, the increased momentum transfer and increased acceleration of the liquid reduces the cross-sectional flow area of jet **20** as it advances so that egress region **16** is made smaller than discharge area **21** for high pressure amplification. I have operated my hydrokinetic amplifier with an egress region area as small as 0.17 times discharge area **21** when liquid input pressure is especially low relative to vapor input pressure. There is reason to believe that egress region **16** could be even smaller.

For high pressure amplification, it is important that the liquid in jet **20** nearly fill egress region **16**, through which it converges. This requires condensing nearly all the vapor by the time jet **20** reaches egress region **16**, which can then be preferably about 90% filled with liquid. Overfilling floods the egress region and stalls the device.

Operating in a high pressure gain mode, my hydrokinetic amplifier has achieved absolute output pressures multiplying the sum of the absolute liquid and vapor input pressures by 4.7, for example, using atmospheric water and vapor inputs to produce an output pressure of 140 psia. Many examples of pressure gain factors range upwards from 3 times the absolute liquid and vapor inputs, and there is reason to believe that present gain factors can be increased. Prior art devices, in contrast, have not achieved a factor of 2 times the absolute liquid and vapor inputs.

For pressure gain, the prior art has used injectors with steam nozzles surrounded by water accelerated along a wall. Currently marketed injectors from Penberthy Division of Houdaille Industries, Inc., Prophetstown, Ill., produce an output pressure of "a little more than the steam pressure" for injectors supplied with water ranging from atmospheric pressure up to about 12 psig. Sellers Injector Systems, Prosser-East Division of Purex Corporation Ltd., Horsham, Pa., reports a higher pressure gain for a line of injectors supplied with tap water at undisclosed pressures assumed to be 40 to 60 psig. One of these models with steam at 40 psia can output 195 psia—for a pressure gain factor of nearly 2, depending on what water pressure is assumed. My hydrokinetic amplifier, using the same water and steam inputs, readily exceeds this.

My hydrokinetic amplifier can accept water input pressures ranging from well below to far above atmospheric pressure, reaching as high as several thousand psia. No prior art jet pump can accept input water over such a wide range of pressures while producing a pressure gain. My hydrokinetic amplifier can also operate with subatmospheric pressure vapor, which cannot be used to drive prior art injectors. Not only is the performance spectrum of my hydrokinetic amplifier broader in ranging much farther over permissible values of liquid and vapor input pressures, but its pressure gain performance is better than the prior art for any comparable inputs.

My hydrokinetic amplifier also invites comparison with prior art fluid heaters having a water jet surrounded by steam flow. Some fluid heaters produce moderate liquid pressure gain at low pressure liquid input values, but they suffer a pressure decrease at higher levels of water input pressure. Their discharge pressures are also less than, instead of several times, the sum of their absolute steam and water input pressures.

HIGH TEMPERATURE OUTPUT

Making the vapor condensation rate high compared to the liquid flow rate produces high output temperatures. Using hotter and higher pressure vapors combined with hotter liquids also produces hotter outputs. In pumping return water to a boiler, for example, hydrokinetic amplifiers can be staged and powered by successively higher pressure vapor as the temperature and pressure of liquid input increases at each successive stage until the final output exceeds the boiler pressure and is as hot as is practically possible.

Another way to increase output temperature is to entrain vapor in the high velocity fluid flow through egress region **16**. More of the same vapor that enters the vapor input nozzle and drives the liquid flow can be entrained at egress region **16** to bring the liquid output temperature close to the vapor temperature. Other vapors, gasses, and liquids can also be entrained.

ANALYSIS OF OPERATION

Analysis of the operation of my hydrokinetic amplifier can be expressed in the following relationship:

$$\frac{P_{out}}{P_{in}} \cong \frac{\Delta P_{out}}{\Delta P_{in}} = F\frac{V_{L2out}}{V_{L2in}} = FC^2\frac{\left(\frac{M_V V_V}{M_L V_L}+1\right)^2}{\left(1+\frac{M_V}{M_L}\right)^2}$$

where:

F = efficiency of said diffuser

C = portion of vapor momentum transferred to liquid

M_V = vapor mass flow rate

M_L = liquid mass flow rate

V_V = vapor velocity at said ingress region

V_L = liquid velocity at said ingress region

P_{in} = liquid pressure input

P_{out} = liquid pressure output

$\Delta P_{out} = P_{out}$—internal pressure at egress region

$\Delta P_{in} = P_{in}$—internal pressure at ingress region

Under the many operating circumstances in which the internal egress region pressure is much less than P_{out} and the internal liquid pressure in the ingress region is much less than P_{in} then:

$$\frac{\Delta P_{out}}{\Delta P_{in}} \sim \frac{P_{out}}{P_{in}}$$

For the special case of a large water input tube and low values of P_{in}, the internal liquid pressure at the ingress region may be an appreciable fraction of P_{in}. In this case, it is appropriate to regard

$$\frac{\Delta P_{out}}{\Delta P_{in}}$$

as the effective pressure gain, which is always given by the equality in the above equation.

From the equation, it is apparent that increasing the velocity and mass flow rate of the vapor at ingress region **14** can have a predominant effect on pressure gain. Liquid velocity and mass flow rate at ingress region **14** are far smaller and not so readily varied, but vapor can be accelerated to supersonic velocities that can greatly increase its transferable momentum.

My hydrokinetic amplifier improves over prior art injectors by increasing the value of C, the decrement from unity of which represents internal losses, mostly from fluid friction. *Marks' Standard Handbook for Mechanical Engineers,* Eighth Edition, McGraw-Hill Book Company, at page 14—14, gives a C value of 0.5 for prior art injectors. My hydrokinetic amplifier can operate at C values of 0.6 and higher. Considerable operating data for my hydrokinetic amplifier shows C values of more than 0.7, and there is reason to believe that 0.8 and possibly even 0.9 can be exceeded.

The F factor representing the efficiency of diffuser **15** can have a value of over 0.9 for diffusers filled with liquid. Prior art fluid heaters, probably for ease of start-up, use diffusers with F factors as low as 0.5. I prefer that diffuser **15** be substantially filled with liquid and have an efficiency factor F at least as high as 0.8.

Operational analysis also indicates that high vapor velocity and vapor mass flow rate at ingress region **14** improve performance for any purpose—whether the goal is pressure amplification, distillation, condensation, subatmospheric operation, or high temperature output. This also results in a high pressure gain, even under circumstances in which output pressure is not the primary objective.

I claim:

1. A hydrokinetic amplifier configured to receive liquid and vapor for condensing said vapor in said liquid, transferring the momentum of said vapor to said liquid, and increasing the pressure of said liquid substantially from input to output, said hydrokinetic amplifier comprising:

a. a liquid input nozzle;

b. a vapor input nozzle;

c. an acceleration chamber having an ingress region and an egress region;

d. a minimum cross-sectional area of said egress region being less than the cross-sectional area of a discharge region of said liquid input nozzle;

e. a wall of said acceleration chamber gradually converging from said ingress region toward said egress region;

f. a diffuser extending from said egress region downstream;

g. said liquid input nozzle being arranged to direct a free liquid jet into said ingress region so that liquid in said jet passes through said acceleration chamber without contacting said converging wall before reaching said egress region;

h. said vapor nozzle having a throat region arranged upstream of a discharge region of said liquid input nozzle and an expanding region arranged from said throat region downstream toward said ingress region so that vapor passing beyond said throat region is expanding upon reaching said discharge region of said liquid nozzle; and

i. said vapor nozzle being arranged for directing said expanding vapor to surround and travel in the direction of said free liquid jet, whereby substantially more than half of said expanding vapor contacts and condenses in said free liquid jet, transferring momentum from said vapor to said liquid to accelerate said liquid toward said egress region so that:

$$\frac{P_{out}}{P_{in}} \cong \frac{\Delta P_{out}}{\Delta P_{in}} = F\frac{V_{L2out}}{V_{L2in}} = FC^2\frac{\left(\frac{M_V V_V}{M_L V_L}+1\right)^2}{\left(1+\frac{M_V}{M_L}\right)^2}$$

where:

F=efficiency of said diffuser

C=portion of vapor momentum transferred to liquid

M_V=vapor mass flow rate

M_L=liquid mass flow rate

V_V=vapor velocity at said ingress region

V_L=liquid velocity at said ingress region

P_{in}=liquid pressure input

P_{out}=liquid pressure output

$\Delta P_{out}=P_{out}$—internal pressure at egress region

$\Delta P_{in}=P_{in}$—internal pressure at ingress region

and wherein C is at least about 0.6.

2. The hydrokinetic amplifier of claim **1** wherein said vapor nozzle is configured to produce maximum thrust.

3. The hydrokinetic amplifier of claim **1** wherein said liquid and vapor input nozzles and said acceleration chamber are arranged so that at least about 90% of said vapor condenses in said free liquid jet before reaching said egress region.

4. The hydrokinetic amplifier of claim **1** wherein the cross-sectional area of said egress region is about 10% larger than the cross-sectional area of the liquid stream passing through said egress region.

5. A hydrokinetic amplifier configured to receive liquid and vapor for condensing said vapor in said liquid and transferring the momentum of said vapor to said liquid, said hydrokinetic amplifier comprising:

a. a liquid input nozzle;

b. a vapor input nozzle;

c. an acceleration chamber having an ingress region and an egress region;

d. a minimum cross-sectional area of said egress region being less than the cross-sectional area of a discharge region of said liquid input nozzle;

e. a wall of said acceleration chamber gradually converging from said ingress region toward said egress region;

f. a diffuser extending from said egress region downstream;

g. said liquid input nozzle being arranged to direct a free liquid jet into said ingress region so that liquid in said jet passes through said acceleration chamber without contacting said converging wall before reaching said egress region; and

h. said vapor nozzle extending from upstream of a discharge region of said liquid input nozzle and having a throat region arranged for directing vapor to surround said free liquid jet at said discharge region of said liquid input nozzle and to travel in the direction of said free liquid jet for a sufficient distance so that substantially more than half of said vapor contacts and condenses in said free liquid jet, transferring momentum from said vapor to said liquid to accelerate said liquid toward said egress region so that:

$$\frac{P_{out}}{P_{in}} \cong \frac{\Delta P_{out}}{\Delta P_{in}} = F\frac{V_{L2out}}{V_{L2in}} = FC^2\frac{\left(\frac{M_V V_V}{M_L V_L}+1\right)^2}{\left(1+\frac{M_V}{M_L}\right)^2}$$

where:

F=efficiency of said diffuser

C=portion of vapor momentum transferred to liquid

M_V=vapor mass flow rate

M_L=liquid mass flow rate

V_V=vapor velocity at said ingress region

V_L=liquid velocity at said ingress region

P_{in}=liquid pressure input

P_{out}=liquid pressure output

$\Delta P_{out}=P_{out}$—internal pressure at egress region

$\Delta P_{in}=P_{in}$—internal pressure at ingress region

and wherein C is at least about 0.6 and F is at least about 0.8.

6. The hydrokinetic amplifier of claim **5** wherein said liquid and vapor input nozzles and said acceleration chamber are arranged so that at least about 90% of said vapor condenses in said free liquid jet before reaching said egress region.

7. The hydrokinetic amplifier of claim **5** wherein said vapor nozzle and said acceleration chamber are arranged so that said vapor reaches sonic velocity in said throat region.

8. The hydrokinetic amplifier of claim **5** wherein the cross-sectional area of said egress region is about 10% larger than the cross-sectional area of the liquid stream passing through said egress region.

9. A hydrokinetic amplifier configured to receive liquid and vapor for condensing said vapor in said liquid and transferring the momentum of said vapor to said liquid, said hydrokinetic amplifier comprising:

a. a liquid input nozzle;

b. a vapor input nozzle;

c. means for supplying vapor at subatmospheric pressure to said vapor nozzle;

d. an acceleration chamber having an ingress region and an egress region;

e. a wall of said acceleration chamber gradually converging from said ingress region toward said egress region;

f. a diffuser extending from said egress region downstream;

g. said liquid input nozzle being arranged to direct a free liquid jet into said ingress region so that liquid in said jet passes through said acceleration chamber without contacting said converging wall before reaching said egress region; and

h. said vapor nozzle being arranged for directing said subatmospheric pressure vapor to surround and travel in the direction of said free liquid jet for a sufficient distance so that substantially more than one-half of said vapor contacts and condenses in said free liquid jet, transferring momentum from said vapor to said liquid to accelerate said liquid toward said egress region so that:

$$\frac{P_{out}}{P_{in}} \approx \frac{\Delta P_{out}}{\Delta P_{in}} = F\frac{V_{L2out}}{V_{L2in}} = FC^2\frac{\left(\frac{M_V V_V}{M_L V_L} + 1\right)^2}{\left(1 + \frac{M_V}{M_L}\right)^2}$$

where:

F=efficiency of said diffuser

C=portion of vapor momentum transferred to liquid

M_V=vapor mass flow rate

M_L=liquid mass flow rate

V_V=vapor velocity at said ingress region

V_L=liquid velocity at said ingress region

P_{in}=liquid pressure input

P_{out}=liquid pressure output

$\Delta P_{out}=P_{out}$—internal pressure at egress region

$\Delta P_{in}=P_{in}$—internal pressure at ingress region

and wherein C is at least about 0.6.

10. The hydrokinetic amplifier of claim **9** wherein said vapor nozzle is configured to produce maximum thrust.

11. The hydrokinetic amplifier of claim **9** wherein said liquid and vapor input nozzles and said acceleration chamber are arranged so that at least about 90% of said vapor condenses in said free liquid jet before reaching said egress region.

12. The hydrokinetic amplifier of claim **9** wherein the cross-sectional area of said egress region is about 10% larger than the cross-sectional area of the liquid stream passing through said egress region.

13. The hydrokinetic amplifier of claim **9** including means for supplying liquid at subatmospheric pressure to said liquid input nozzle.

14. The hydrokinetic amplifier of claim **13** wherein the minimum cross-sectional area of said egress region is less than the cross-sectional area of a discharge region of said liquid input nozzle.

15. The hydrokinetic amplifier of claim **9** wherein the minimum cross-sectional area of said egress region is less than the cross-sectional area of a discharge region of said liquid input nozzle.

16. The hydrokinetic amplifier of claim **15** wherein said vapor nozzle is configured to produce maximum thrust.

17. The hydrokinetic amplifier of claim **16** wherein said liquid and vapor input nozzles and said acceleration chamber are arranged so that at least about 90% of said vapor condenses in said free liquid jet before reaching said egress region.

18. The hydrokinetic amplifier of claim **17** wherein the cross-sectional area of said egress region is up to about 10% larger than the cross-sectional area of the liquid stream passing through said egress region.

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